Energy Modeling for the LEED® Energy & Atmosphere Credit 1

SURVEY

LEED and Energy Modeling
Does your firm or organization:

1. Participate in LEED® projects?
2. Perform energy modeling?
3. Perform energy modeling for LEED® projects?
AGENDA

A. Introduction
1. Brief overview of LEED® rating system
2. Energy modeling and applications
3. Key conditions for high quality energy modeling

B. Energy Modeling for LEED EAc1
1. Overview of Performance Rating Method
2. Alternate approaches to LEED® EAc1 Analysis
4. Software productivity features

LEED® 2009 OVERVIEW

LEED® 2009 New Construction and Renovation

- Energy & Atmosphere: 35 pts
- Materials & Resources: 14 pts
- Water Efficiency: 10 pts
- Sustainable Sites: 26 pts
- Indoor Environmental Quality: 15 pts

- 5 Base Categories
- 8 Prerequisites: 32 Credits
- 100 Base Points
- 6 Innovation Points
- 4 Regional Points
- 110 Total Points

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LEED® 2009 OVERVIEW

LEED® 2009 OVERVIEW

EA Credit 1 – Energy Modeling Approach
Earn 1 to 19 pts based on energy cost savings
Different scales for New Construction and Renovation

Existing Bldg Renovation:
8% = 1 pt to 44% = 19 pts

New Construction:
12% = 1 pt to 48% = 19 pts

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ENERGY MODELING

**Alternate Terms**

- Energy Modeling
- Energy Simulation
- Energy Analysis
- Energy Estimating
- Opcost Analysis

**Definition**

*Classical Energy Modeling - Creating a computer model of a building and its systems to predict annual energy consumption.*

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**Original Applications (1960s-Present)**

- Schematic Design – Screening alternatives
- Detailed Design – Selection, optimization of design

**Recent Applications (2000-Present)**

- LEED® EA Credit 1, Prerequisite 2
- ASHRAE 90.1 Energy Cost Budget
- EPACT 2005 Energy Efficient Com’l Building Tax Deduction

**Future Applications (Beyond 2010)**

- ASHRAE Standard 189.1-2009
- ASHRAE EQ Building Labeling Program

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ENERGY MODELING

Key Conditions for High Quality Modeling

1. The Energy Modeling Tool
   Appropriate, robust tool matched to objectives

2. The Energy Modeler
   Proficient with:
   - HVAC engineering fundamentals
   - Chosen energy modeling software
   - Procedure required to achieve objective

PERFORMANCE RATING METHOD

Energy Modeling Procedure for EAc1

Performance Rating Method (PRM)
Rates energy efficiency of buildings which exceed energy code provisions

ASHRAE 90.1-2007 – Appendix G

Requirements for:
- Software Tool Used
- Modeling Proposed Building
- Modeling Baseline Building
PERFORMANCE RATING METHOD

PRM – Basic Concepts

Basic Concept

Compare Proposed Design vs. Reference Case to determine energy cost savings.

Savings Calculation

\[
\% \text{ Savings} = 100 \times \frac{(\text{Baseline Energy Cost}) - (\text{Proposed Energy Cost})}{(\text{Baseline Energy Cost})}
\]

All end uses for energy included.

% Savings translates into LEED® credit points.

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LEARNING EXERCISE

Question #1

For the following example, write the equation for calculating PRM energy cost savings.

Example:

New construction project
Proposed Building annual energy cost = $108,000
Baseline Building annual energy cost = $137,000

\[
\% \text{ Savings} = 100 \times \frac{(\text{Baseline Cost} - \text{Proposed Cost})}{(\text{Baseline Cost})}
\]

\[
\% \text{ Savings} = 100 \times \frac{($137,000 - $108,000)}{($137,000)} = 21.2\%
\]
LEARNING EXERCISE

Question #2
For a new construction project, if the PRM energy cost savings is 21.2%, how many LEED EAc1 points would be earned?

Points Earned = 5 pts

PERFORMANCE RATING METHOD

Proposed Building

Key Principles
A version of designed building; not the actual bldg.
Modifications made to comply with PRM rules.
Energy cost not necessarily the actual cost for design.

Example Modifications Required
Conditioned spaces must be heated and cooled - even when actual is heating-only or cooling-only.
HVAC fans run continuously for occupied periods.
Manually operated shades not modeled.
PERFORMANCE RATING METHOD

Baseline Building - Basics

Key Principles
Baseline = Minimum Prescriptive
As if building only designed to meet minimum code requirements

Key Characteristics
Same size, shape, usage, # floors, site as Proposed.
Walls, Roofs, Floors: Prescriptive performance.
Fenestration: Prescriptive performance
HVAC, SHW: Prescriptive requirements and min eqpt efficiency.
Lighting: Prescriptive lighting power density.

PRM Method…What Is The Procedure?

Proposed Building Baseline Building(s)

<table>
<thead>
<tr>
<th>Component</th>
<th>Proposed Building ($)</th>
<th>0° Rotation (same as Proposed)</th>
<th>90° Rotation</th>
<th>180° Rotation</th>
<th>270° Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC Sub-Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lights</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Misc. Electric</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Misc. Fuel Use</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-HVAC Sub-Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HVAC Sub-Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lights</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Misc. Electric</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Misc. Fuel Use</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GRAND TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ANALYSIS APPROACH

### Just-Do-It
1. Brute force approach.
2. Enter data, run calculations, review results.
3. Figure out analysis as you go.

### Plan-Then-Execute
1. Finesse approach.
2. Carefully plan and organize analysis per PRM rules.
3. Enter data, run calculations, review results.

<table>
<thead>
<tr>
<th>Risks:</th>
<th>Benefits:</th>
</tr>
</thead>
<tbody>
<tr>
<td>More Time</td>
<td>Less Time</td>
</tr>
<tr>
<td>More Time</td>
<td>Less Time</td>
</tr>
<tr>
<td>More Time</td>
<td>Less Time</td>
</tr>
<tr>
<td>More Time</td>
<td>Less Time</td>
</tr>
<tr>
<td>More Time</td>
<td>Less Time</td>
</tr>
<tr>
<td>More Time</td>
<td>Less Time</td>
</tr>
<tr>
<td>More Time</td>
<td>Less Time</td>
</tr>
</tbody>
</table>

Time = $$

PLAN-THEN-EXECUTE APPROACH

### Plan-Then-Execute Method
1. Choose Software
2. Determine Scope for Energy Modeling
3. Determine Space Classifications
4. Determine Thermal Block Strategy
5. Finish Modeling Plan for Proposed Building
6. Create Modeling Plan for Baseline Building
7. Survey the Competition
8. Execute Analysis
Plan-Then-Execute Method

1. Choose Software
2. Determine Scope for Energy Modeling
3. Determine Space Classifications
4. Determine Thermal Block Strategy
5. Finish Modeling Plan for Proposed Building
6. Create Modeling Plan for Baseline Building
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8. Execute Analysis

SOFTWARE SELECTION

PRM - Minimum Software Requirements

**Basic**
- Computer based program
- Approved by rating authority
- 8,760 hours per year analysis
- Model proposed bldg features and/or can use exceptional calculation
- Model baseline bldg features
- Determine proposed and baseline energy costs, or supply energy use

**Thermal Load Modeling**
- Model hourly variations of internal loads, setpoints, HVAC operation, all days of week.
- Model thermal mass effects
- Model ten or more thermal zones.
SOFTWARE SELECTION

PRM - Minimum Software Requirements

Equipment Modeling
Model capacity + efficiency corrections curves for equipment.
Model part-load performance curves for equipment
Model air-side economizers with integrated control.

System Design
Perform design calculations to size HVAC equipment capacity, air flow, water flow.

Software Testing
Vendor to test per ASHRAE Standard 140 and make results available.

SOFTWARE SELECTION

Beyond Minimum Compliance

Additional Considerations:
1. Technical capabilities
2. LEED®-oriented features for efficiency
3. Ease of Use
4. Technical Support
5. Training
6. Cost

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Plan-Then-Execute Method

1. Choose Software
2. **Determine Scope for Energy Modeling**
3. Determine Space Classifications
4. Determine Thermal Block Strategy
5. Finish Modeling Plan for Proposed Building
6. Create Modeling Plan for Baseline Building
7. Survey the Competition
8. Execute Analysis

 SCOPE OF ENERGY MODEL

Basic Principles

_Scope = How much of building is modeled_

1. **New Construction**
   Model whole building

2. **Renovation or Addition to Existing Building**
   Model whole building
   =OR=
   Model only addition or portion being renovated (specific requirements)
SCOPE OF ENERGY MODEL

Why Scope Matters
(Learning Exercise #7)

Advantages of Reduced Scope
Faster, cheaper modeling
Can affect LEED® EAc1 points potential

Example:
Office Building
30,000 sqft existing.
10,000 sqft addition.

<table>
<thead>
<tr>
<th></th>
<th>Model Whole Building</th>
<th>Model Addition Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modeled Floor Area</td>
<td>40,000 sqft</td>
<td>10,000 sqft</td>
</tr>
<tr>
<td>Energy Cost Savings</td>
<td>$5,000</td>
<td>$5,000</td>
</tr>
<tr>
<td>Baseline Energy Cost</td>
<td>$61,000</td>
<td>$17,000</td>
</tr>
<tr>
<td>% Savings</td>
<td>8.2%</td>
<td>29.4%</td>
</tr>
<tr>
<td>Points Earned</td>
<td>1 pt</td>
<td>11 pts</td>
</tr>
</tbody>
</table>

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SCOPE OF ENERGY MODEL

Conditions for Reduced Scope
(All conditions must be met)

1. Renovation or addition to existing building
2. HVAC systems completely separate in part modeled and not modeled.
3. Little or no heat flow through separating partitions; similar setpoints and schedules.
4. Flat energy prices or separate energy meter for renovation.
LEARNING EXERCISE

What is the required scope for the example below? Whole building or addition only.

Example:
(1) Existing office building, 4 floors, 64,000 sqft.
(2) Addition of 18,000 sqft office space to be constructed.
(3) Flat energy prices will be used in model.
(4) HVAC for addition is hydronic fan coil units
(5) FCUs to be connected to existing CW and HW plants.

Answer: **Whole Building**

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**Plan-Then-Execute Method**

1. Choose Software
2. Determine Scope for Energy Modeling
3. **Determine Space Classifications**
4. Determine Thermal Block Strategy
5. Finish Modeling Plan for Proposed Building
6. Create Modeling Plan for Baseline Building
7. Survey the Competition
8. Execute Analysis
SPACE USE CLASSIFICATION

Importance

Can affect:
- Thermal block strategy
- Baseline system selection
- Lighting power density (Baseline and sometimes Proposed)
- Schedules (if actual not known)
- Occupant, receptacle, SHW loads (if actual not known)

Classification Rules

Use Building Area method or Space-by-Space method.
Consistently apply throughout building.
Multi-Use Buildings – Can use different Building Usage types.
Usage Not Known - Choose “Office” type.

Plan-Then-Execute Method

1. Choose Software
2. Determine Scope for Energy Modeling
3. Determine Space Classifications
4. Determine Thermal Block Strategy
5. Finish Modeling Plan for Proposed Building
6. Create Modeling Plan for Baseline Building
7. Survey the Competition
8. Execute Analysis
THERMAL BLOCKS

Example: Modeling Building As Designed

Conditions
Rectangular office building
4 stories
60,000 sqft
152 zones

Consequences
1 Proposed Bldg
4 Baseline Bldgs
152 zones x 5 buildings
= 760 zones

THERMAL BLOCKS

Definition and Concepts

ASHRAE 90.1 Definition

Thermal Block – A collection of one or more HVAC zones grouped together for simulation purposes. Spaces need not be contiguous to be combined within a single thermal block.

Concepts
Requires engineering judgment
Simplifies model without degrading accuracy
Key: Combine thermally similar zones into a single block.

Thermally Similar Means...
Similar load density
Similar time-dependent behavior
THERMAL BLOCKS

Basic Principles

Principles for Creating Thermal Blocks
Separate thermal blocks should be created for:
1. Zones with different building use or space use classifications
2. Ground floor, intermediate floors, top floor
3. Perimeter and interior areas.
4. Zones with glazed exterior walls with orientation differing by >= 45°
5. Corner zones
6. Different or different kinds of HVAC systems

Application of Thermal Blocks

Conditions
Office building example
THERMAL BLOCKS

Application of Thermal Blocks

Conditions
Office building example

Benefits
27 blocks / bldg
27 blocks x 5 bldgs
= 135 blocks
80% reduction vs. 760 zones
THERMAL BLOCKS

Rules for Specific Scenarios

**HVAC Zones Designed**
1. Blocks are built from designed zones.
2. Corners must be separate.

**HVAC Zones Not Yet Designed**
1. Construct hypothetical blocks
2. Perimeter and interior separate.
3. Perimeter - 15 ft from exterior wall.
4. Corners can be divided.

**Multi-Family Residential**
1. Blocks built from designed units.
2. Corners must be separate.

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LEARNING EXERCISE

**Question #5**
For the sample building below use thermal block principles to reduce the number of thermal blocks (zones) modeled.

Minimum Blocks per Floor =
Total Blocks for Building =

4-Story Office
34 designed zones per floor.
136 zones total
Floor-by-floor
VAV AHUs
**Learning Exercise**

**Question #5 (continued)**

("Good" Answer)

Minimum Blocks per Floor = __12___

Total Blocks for Building = __3 x 12 = 36___

![Diagram with blocks labeled 1 to 12 and 3 sets of 4 blocks]

**Question #5 (continued)**

("Better" Answer)

Minimum Blocks per Floor = __9___

Total Blocks for Building = __3 x 9 = 27___

![Diagram with blocks labeled 1 to 12 and 3 sets of 3 blocks]
Plan-Then-Execute Method

1. Choose Software
2. Determine Scope for Energy Modeling
3. Determine Space Classifications
4. Determine Thermal Block Strategy
5. Finish Modeling Plan for Proposed Building
6. Create Modeling Plan for Baseline Building
7. Survey the Competition
8. Execute Analysis

PROPOSED BUILDING MODEL

Finishing the Modeling Plan

Proposed Building Model
Start with actual design.
Make allowed simplifications
Make required modifications

Approach
Assemble and review modeling checklist for Proposed Building
PROPOSED BUILDING MODEL

Finishing the Modeling Plan

Sample Checklist
Illustrates checklist concept and application.
For New Construction scenarios only.
Includes key details; omits others due to space limitations.

Elements
General modeling issues       HVAC Systems
Schedules                    Service Hot Water
Envelope                     Receptacle
Lighting                     Energy Prices

(1) General Modeling Issues

<table>
<thead>
<tr>
<th>Item</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope of model</td>
<td>Simplification</td>
</tr>
<tr>
<td>Space use classification</td>
<td></td>
</tr>
<tr>
<td>Thermal blocks</td>
<td>Simplification</td>
</tr>
<tr>
<td>Consistent with design documents</td>
<td></td>
</tr>
<tr>
<td>Include all end uses for energy</td>
<td></td>
</tr>
</tbody>
</table>

Sample checklists apply to New Construction scenario only and include key issues. Refer to 90.1 Appendix G for full requirements.

(2) Schedules

<table>
<thead>
<tr>
<th>Item</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Known: Use actual</td>
<td></td>
</tr>
<tr>
<td>Not Known: Use typical (90.1 User's Manual App G)</td>
<td></td>
</tr>
<tr>
<td>HVAC Fans - Run continuously occupied; cycle unoccupied</td>
<td>Not Actual</td>
</tr>
</tbody>
</table>
### PROPOSED BUILDING MODEL

#### (3) Envelope

<table>
<thead>
<tr>
<th>Item</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔ Model wall, roof, floors, fenestration assemblies as designed</td>
<td></td>
</tr>
<tr>
<td>✔ Uninsulated assemblies</td>
<td>Simplification</td>
</tr>
<tr>
<td>✔ Simplified model flush with wall, or weighted avg U-value.</td>
<td></td>
</tr>
<tr>
<td>✔ Assembly &lt; 5% total area for assembly type.</td>
<td>Simplification</td>
</tr>
<tr>
<td>✔ Include in larger assembly type, if thermally similar.</td>
<td></td>
</tr>
<tr>
<td>✔ Azimuth or tilt within 45° - model as same orientation</td>
<td>Simplification</td>
</tr>
<tr>
<td>✔ Exterior Roof</td>
<td>Not Actual</td>
</tr>
<tr>
<td>✔ Reflectivity = 0.45 if ( \rho &gt; 0.70 ) and ( \varepsilon &gt; 0.75 ) OR (SRI ( \geq 82 ))</td>
<td></td>
</tr>
<tr>
<td>✔ Reflectivity = 0.30 otherwise</td>
<td></td>
</tr>
<tr>
<td>✔ Manually operated fenestration shading - Exclude</td>
<td>Not Actual</td>
</tr>
<tr>
<td>✔ Automatically operated fenestration shading - May Include</td>
<td></td>
</tr>
<tr>
<td>✔ Permanent shading devices (e.g. fins, overhangs) - May include</td>
<td></td>
</tr>
</tbody>
</table>

Sample checklists apply to New Construction scenario only and include key issues. Refer to 90.1 Appendix G for full requirements.

#### (4) Lighting

<table>
<thead>
<tr>
<th>Item</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔ System Designed - Use designed lighting power (per 9.1.3, 9.1.4)</td>
<td></td>
</tr>
<tr>
<td>✔ System Not Designed - Define per Building Area Method</td>
<td></td>
</tr>
<tr>
<td>✔ Portable lighting (e.g. task, furniture-mounted) - must include.</td>
<td></td>
</tr>
<tr>
<td>✔ Exempt lighting (e.g. theatrical lighting) - must include.</td>
<td></td>
</tr>
<tr>
<td>✔ Exterior lighting (e.g. façade, parking) - must include.</td>
<td></td>
</tr>
<tr>
<td>✔ Automatic daylighting controls - may include.</td>
<td></td>
</tr>
<tr>
<td>✔ via direct modeling or adjusted schedules</td>
<td></td>
</tr>
<tr>
<td>✔ Controls exceeding Mandatory provisions - may take credit</td>
<td></td>
</tr>
<tr>
<td>✔ via reduced LPD or adjusted schedules</td>
<td></td>
</tr>
<tr>
<td>✔ Applies to programmable timing control and/or occ. sensors</td>
<td></td>
</tr>
</tbody>
</table>

Sample checklists apply to New Construction scenario only and include key issues. Refer to 90.1 Appendix G for full requirements.
### PROPOSED BUILDING MODEL

#### (5) HVAC Systems

<table>
<thead>
<tr>
<th>Item</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Designed - Model consistent with documents</td>
<td></td>
</tr>
<tr>
<td>No Heating System Designed:</td>
<td>Not Actual</td>
</tr>
<tr>
<td>Add heating. Use electric heat and baseline system type</td>
<td></td>
</tr>
<tr>
<td>No Cooling System Designed:</td>
<td>Not Actual</td>
</tr>
<tr>
<td>Add cooling. Use baseline system type</td>
<td></td>
</tr>
<tr>
<td>HW and CW Plants - Do not model pipe heat gain or loss</td>
<td>Not Actual</td>
</tr>
</tbody>
</table>

#### (6) Service Hot Water

<table>
<thead>
<tr>
<th>Item</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHW Designed - Model as designed</td>
<td></td>
</tr>
<tr>
<td>SHW Not Designed - Model per baseline rules.</td>
<td></td>
</tr>
<tr>
<td>No SHW Loads Exist - Do not model SHW</td>
<td></td>
</tr>
</tbody>
</table>

Sample checklists apply to New Construction scenario only and include key issues. Refer to 90.1 Appendix G for full requirements.

#### (7) Receptacle and Process Loads

<table>
<thead>
<tr>
<th>Item</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receptacle and process loads - Must include.</td>
<td></td>
</tr>
<tr>
<td>Loads Known - Use actual data.</td>
<td></td>
</tr>
<tr>
<td>Loads Not Known - May estimate.</td>
<td></td>
</tr>
<tr>
<td>Resource: Table G-B in 90.1 User’s Manual.</td>
<td></td>
</tr>
</tbody>
</table>

#### (8) Energy Prices

<table>
<thead>
<tr>
<th>Item</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Approach - Use EIA flat prices (by state)</td>
<td></td>
</tr>
<tr>
<td>Energy Information Administration: <a href="http://www.eia.doe.gov">www.eia.doe.gov</a></td>
<td></td>
</tr>
<tr>
<td>Detailed Approach - Use actual utility rate structures</td>
<td></td>
</tr>
<tr>
<td>Must use one approach for all energy and fuels</td>
<td></td>
</tr>
</tbody>
</table>

Sample checklists apply to New Construction scenario only and include key issues. Refer to 90.1 Appendix G for full requirements.
Plan-Then-Execute Method
1. Choose Software
2. Determine Scope for Energy Modeling
3. Determine Space Classifications
4. Determine Thermal Block Strategy
5. Finish Modeling Plan for Proposed Building
6. **Create Modeling Plan for Baseline Building**
7. Survey the Competition
8. Execute Analysis

BASELINE BUILDING MODEL
Creating the Baseline Modeling Plan

**Baseline Building Model**
Start with proposed building model.
Preserve elements which must be identical
Replace elements which must be prescriptive.

**Approach**
Assemble and review modeling checklist for Baseline Building

**Sample Checklist**
Illustrates checklist concept and application.
For New Construction scenarios only.
Includes key details; omits others due to space limitations.
PROPOSED BUILDING MODEL

Baseline Modeling Rules

Overview

<table>
<thead>
<tr>
<th>Category</th>
<th>General Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Basic size, shape, usage.</td>
<td></td>
</tr>
<tr>
<td>2. Envelope - Opaque Elements</td>
<td></td>
</tr>
<tr>
<td>3. Envelope – Fenestration</td>
<td></td>
</tr>
<tr>
<td>4. Lighting</td>
<td></td>
</tr>
<tr>
<td>5. Service Hot Water</td>
<td></td>
</tr>
<tr>
<td>6. HVAC Systems</td>
<td></td>
</tr>
</tbody>
</table>

BASELINE BUILDING MODEL

(1) General Modeling Issues

<table>
<thead>
<tr>
<th>Item</th>
<th>Same as Proposed</th>
<th>Prescriptive</th>
<th>Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space use classifications</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal blocks</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of floors</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditioned floor area</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature, humidity setpoints</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receptacle and process loads</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schedules (exceptions for lighting controls and DCV)</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulation program</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weather data</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy prices</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sample checklists apply to New Construction scenario only and include key issues. Refer to 90.1 Appendix G for full requirements.
## BASELINE BUILDING MODEL

### (2) Envelope – Opaque Elements

<table>
<thead>
<tr>
<th>Item</th>
<th>Same as Proposed</th>
<th>Prescriptive</th>
<th>Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface dimensions, orientation, tilt</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof reflectivity</td>
<td></td>
<td></td>
<td>Fixed at $\rho=0.30$</td>
</tr>
<tr>
<td>Self-shading</td>
<td></td>
<td></td>
<td>Do not model</td>
</tr>
<tr>
<td>Envelope Assemblies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Above grade exterior walls</td>
<td>X</td>
<td></td>
<td>Steel framed</td>
</tr>
<tr>
<td>Roofs</td>
<td>X</td>
<td></td>
<td>Insulation above deck</td>
</tr>
<tr>
<td>Floors</td>
<td>X</td>
<td></td>
<td>Steel joist</td>
</tr>
<tr>
<td>Slab on Grade</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opaque doors</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sample checklists apply to New Construction scenario only and include key issues. Refer to 90.1 Appendix G for full requirements.

### (3) Envelope – Fenestration

<table>
<thead>
<tr>
<th>Item</th>
<th>Same as Proposed</th>
<th>Prescriptive</th>
<th>Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fenestration dimensions, orientation, tilt</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Above Grade Walls - Window-to-Wall Ratio (WWR)</td>
<td>X</td>
<td>X</td>
<td>Smaller of Proposed or 40%</td>
</tr>
<tr>
<td>Skylight-to-Roof Ratio (SRR)</td>
<td>X</td>
<td>X</td>
<td>Smaller of Proposed or 5%</td>
</tr>
<tr>
<td>U-value and SHGC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-shading</td>
<td></td>
<td></td>
<td>Do not model</td>
</tr>
<tr>
<td>Vertical Fenestration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recesses, reveals</td>
<td></td>
<td></td>
<td>Do not model</td>
</tr>
<tr>
<td>Permanent shading projections (e.g., fins, overhangs)</td>
<td></td>
<td></td>
<td>Do not model</td>
</tr>
<tr>
<td>Interior shades (blinds, drapes, shades)</td>
<td></td>
<td></td>
<td>Do not model</td>
</tr>
</tbody>
</table>

Sample checklists apply to New Construction scenario only and include key issues. Refer to 90.1 Appendix G for full requirements.
BASELINE BUILDING MODEL

(4) Lighting

<table>
<thead>
<tr>
<th>Item</th>
<th>Same as Proposed</th>
<th>Prescriptive</th>
<th>Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space or building use classifications</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting power density</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Schedules</td>
<td></td>
<td>X</td>
<td>Reflect mandatory control requirements</td>
</tr>
</tbody>
</table>

(5) Service Hot Water

<table>
<thead>
<tr>
<th>Item</th>
<th>Same as Proposed</th>
<th>Prescriptive</th>
<th>Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy source</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SHW is designed.</td>
<td></td>
<td>X</td>
<td>per 7.4.1, 7.4.2</td>
</tr>
<tr>
<td>SHW not designed but will exist.</td>
<td></td>
<td>X</td>
<td>Electric, per 7.4.2</td>
</tr>
</tbody>
</table>

Sample checklists apply to New Construction scenario only and include key issues. Refer to 90.1 Appendix G for full requirements.

BASELINE BUILDING MODEL

(6) HVAC Systems

**Procedure**

1. Determine baseline system type based on proposed building type and size, and heating type (G3.1.1)
2. Apply general system requirements (G3.1.2)
3. Apply system-specific requirements (G3.1.3)

Sample checklists apply to New Construction scenario only and include key issues. Refer to 90.1 Appendix G for full requirements.
### BASELINE BUILDING MODEL

#### (6) HVAC Systems – System Determination

**Residential**
- **System 1 – PTAC**
- **System 2 – PTHP**

**Non-Residential**
- 1 to 3 floors AND < 25,000 ft²
  - **System 3 – PSZ-AC**
  - **System 4 – PSZ-HP**

- [4 or 5 floors and < 25,000 ft²] OR [1 to 5 floors & 25,000 ft² to 150,000 ft²]
  - **System 5 – Packaged VAV w/Reheat**
  - **System 6 – Packaged VAV w/PFPMBX**

- >5 floors OR >150,000 ft²
  - **System 7 – VAV w/Reheat**
  - **System 8 – VAV w/PFPMBX**

---

#### BASELINE BUILDING MODEL

#### (6) HVAC Systems – Baseline Systems

<table>
<thead>
<tr>
<th>#</th>
<th>System Type</th>
<th>Fan Control</th>
<th>Cooling Type</th>
<th>Heating Type</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pkg Terminal AC</td>
<td>CAV</td>
<td>DX</td>
<td>HW fossil fuel boiler</td>
<td>1 per zone</td>
</tr>
<tr>
<td>2</td>
<td>Pkg Terminal Heat Pump</td>
<td>CAV</td>
<td>DX</td>
<td>Electric heat pump</td>
<td>1 per zone</td>
</tr>
<tr>
<td>3</td>
<td>Pkg Rooftop AC</td>
<td>CAV</td>
<td>DX</td>
<td>Fossil fuel furnace</td>
<td>1 per zone</td>
</tr>
<tr>
<td>4</td>
<td>Pkg Rooftop Heat Pump</td>
<td>CAV</td>
<td>DX</td>
<td>Electric heat pump</td>
<td>1 per zone</td>
</tr>
<tr>
<td>5</td>
<td>Pkg Rooftop VAV w/Reheat</td>
<td>VAV</td>
<td>DX</td>
<td>HW fossil fuel boiler</td>
<td>1 per zone</td>
</tr>
<tr>
<td>6</td>
<td>Pkg Rooftop VAV w/PFPMBX</td>
<td>VAV</td>
<td>DX</td>
<td>Electric resistance</td>
<td>1 per floor</td>
</tr>
<tr>
<td>7</td>
<td>VAV AHU w/Reheat</td>
<td>VAV</td>
<td>Chilled Water</td>
<td>HW fossil fuel boiler</td>
<td>1 per floor</td>
</tr>
<tr>
<td>8</td>
<td>VAV AHU w/PFPMBX</td>
<td>VAV</td>
<td>Chilled Water</td>
<td>Electric resistance</td>
<td>1 per floor</td>
</tr>
</tbody>
</table>

Data applies to New Construction scenario only. Refer to 90.1 Appendix G for full requirements.
### BASELINE BUILDING MODEL

#### (6) HVAC Systems – General System Requirements

<table>
<thead>
<tr>
<th>Item</th>
<th>Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC equipment efficiency</td>
<td>Mandatory minimum efficiency per Section 6</td>
</tr>
<tr>
<td>Cooling equipment capacity</td>
<td>Calculated peak load +15%</td>
</tr>
<tr>
<td>Heating equipment capacity</td>
<td>Calculated peak load +25%</td>
</tr>
<tr>
<td>Outdoor air economizer</td>
<td>Specific rules for inclusion and high limit shutoff</td>
</tr>
<tr>
<td>Supply CFM sizing</td>
<td>Larger of CFM from 20°F ΔT or ventilation airflow.</td>
</tr>
<tr>
<td>Minimum outdoor ventilation airflow</td>
<td>Must match Proposed (DCV exception)</td>
</tr>
<tr>
<td>System fan power</td>
<td>Calculate per Baseline Fan Power Allowance procedure (G3.1.2.9)</td>
</tr>
<tr>
<td>Exhaust air recovery</td>
<td>Specific rules for inclusion, eqpt efficiency</td>
</tr>
<tr>
<td>Unmet load hours</td>
<td>Proposed and Baseline both =&lt; 300 hrs</td>
</tr>
<tr>
<td></td>
<td>Proposed cannot exceed Baseline by &gt; 50 hrs</td>
</tr>
</tbody>
</table>

Sample checklists apply to New Construction scenario only and include key issues. Refer to 90.1 Appendix G for full requirements.

### BASELINE BUILDING MODEL

#### (6) HVAC Systems – System-Specific Requirements

<table>
<thead>
<tr>
<th>Item</th>
<th>Rules Specify</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air source heat pumps</td>
<td>Electric auxiliary; auxiliary not allowed &gt;40°F</td>
</tr>
<tr>
<td>Hot water boiler plants</td>
<td>Plant configuration, control, pump performance.</td>
</tr>
<tr>
<td>Chilled water plants</td>
<td>Plant configuration, control, performance of pumps, cooling towers and cooling tower fans.</td>
</tr>
<tr>
<td>VAV supply fan</td>
<td>VFD, part load performance</td>
</tr>
<tr>
<td>VAV supply air</td>
<td>Supply temperature control for cooling.</td>
</tr>
<tr>
<td>VAV air terminals</td>
<td>Minimum airflow settings</td>
</tr>
</tbody>
</table>

Sample checklists apply to New Construction scenario only and include key issues. Refer to 90.1 Appendix G for full requirements.
Plan-Then-Execute Method

1. Choose Software
2. Determine Scope for Energy Modeling
3. Determine Space Classifications
4. Determine Thermal Block Strategy
5. Finish Modeling Plan for Proposed Building
6. Create Modeling Plan for Baseline Building
7. **Survey the Competition**
8. Execute Analysis

SURVEYING THE COMPETITION

**Basic Principles**

**Concepts**
- Proposed competes with Baseline.
- Differentiation between Proposed and Baseline – Qualifies Proposed as high performance and earns LEED® points
- Survey differences, assess potential before assembling the models.

**Outcomes**
- Go – Good potential for savings and points exists; proceed.
- No-Go – Poor potential; reconsider design or look elsewhere for pts.

**Areas of Focus**
- Envelope – Walls, Roofs, Floors
- Envelope – Fenestration
- Lighting
- HVAC
- SHW

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### Example #1

**Surveying the Competition**

Single story office building  
23,000 sqft conditioned floor area  
Kansas City, MO (Climate Zone 4A)

<table>
<thead>
<tr>
<th>Category</th>
<th>Proposed</th>
<th>Baseline</th>
<th>Differentiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Envelope - Walls</td>
<td>Mass Wall</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>U = 0.055, R-14 c.i.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Envelope - Roof</td>
<td>Built-up roof, insul above steel deck</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>U = 0.047, R-20 c.i.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Envelope - Floor</td>
<td>Unheated slab, F = 0.650</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Envelope - Fenestration</td>
<td>WWR = 20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>U = 0.59, SHGC = 0.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting - Interior</td>
<td>1.0 W/sqft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HVAC System</td>
<td>Single Zone CAV, ASHP</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electric auxiliary heat</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11.1 EER, 3.3 COP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Example #2

**Surveying the Competition**

Single story office building  
23,000 sqft conditioned floor area  
Kansas City, MO (Climate Zone 4A)

<table>
<thead>
<tr>
<th>Category</th>
<th>Proposed</th>
<th>Baseline</th>
<th>Differentiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Envelope - Walls</td>
<td>Mass Wall</td>
<td>Steel Framed Wall</td>
<td></td>
</tr>
<tr>
<td></td>
<td>U = 0.040, R-21 c.i.</td>
<td>U = 0.064, R-13 and R-7.5 c.i.</td>
<td></td>
</tr>
<tr>
<td>Envelope - Roof</td>
<td>Built-up roof, insul above steel deck</td>
<td>Insulation above deck</td>
<td></td>
</tr>
<tr>
<td></td>
<td>U = 0.032, R-30 c.i.</td>
<td>U = 0.048, R-20 c.i.</td>
<td></td>
</tr>
<tr>
<td>Envelope - Floor</td>
<td>Unheated slab, F = 0.650</td>
<td>Unheated slab, F = 0.730</td>
<td></td>
</tr>
<tr>
<td>Envelope - Fenestration</td>
<td>WWR = 20%</td>
<td>WWR = 29%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>U = 0.40, Shgc = 0.29</td>
<td>U = 0.59, Shgc = 0.40</td>
<td></td>
</tr>
<tr>
<td>Lighting - Interior</td>
<td>1.0 W/sqft</td>
<td>1.0 W/sqft, Building Area Method</td>
<td></td>
</tr>
<tr>
<td>HVAC System</td>
<td>Ground Source Heat Pumps</td>
<td>System 4 - PSZ-HP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gas Boiler Auxiliary Heat</td>
<td>Electric auxiliary heat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16.5 EER, 3.4 COP</td>
<td>11.0 EER, 3.3 COP</td>
<td></td>
</tr>
</tbody>
</table>
Plan-Then-Execute Method

1. Choose Software
2. Determine Scope for Energy Modeling
3. Determine Space Classifications
4. Determine Thermal Block Strategy
5. Finish Modeling Plan for Proposed Building
6. Create Modeling Plan for Baseline Building
7. Survey the Competition
8. **Execute Analysis**
SOFTWARE SELECTION REVISITED

Key Conditions for High Quality Modeling

1. The Energy Modeling Tool
   Appropriate, robust tool matched to objectives

2. The Energy Modeler
   Proficient with:
   - HVAC engineering fundamentals
   - Chosen energy modeling software
   - Procedure required to achieve objective

SOFTWARE SELECTION REVISITED

Key Conditions for Efficient Modeling

1. The Energy Modeling Tool
   Provides features to automate PRM-related tasks.

2. The Energy Modeler
   Uses efficient approach (e.g. Plan-then-Execute)
SOFTWARE SELECTION REVISITED

Challenges for Efficient Modeling

The Problem
Rating procedures require specialized tasks.
Outside normal scope of energy modeling.
Tasks can be labor intensive

Proposed Solution
Automation of key PRM tasks.

SOFTWARE SELECTION REVISITED

Sample High Impact Tasks for Automation

Inputs
1. Copying entire Proposed Building as basis for Baseline
2. Efficiently converting data to prescriptive – assemblies, lighting, systems
3. Rotating baseline building

Calculations
1. Setting eqpt capacity based on 15% and 25% factors
2. Setting eqpt efficiency per ASHRAE 90.1 minimums
3. Decompiling EERs and COPs into compressor and fan components
4. Performing baseline fan power allowance calculation (G3.1.2.9)
5. Setting PFPMBX fan power based on W/CFM specification
Thank you

Any Questions?